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AUTHOR Pozzi, S.; And Others
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ABSTRACT

Information technology tools associated with various educational activities often rely on different models of the needed information, support different cooperative styles, and are based on different media and technologies. The architecture of an open software platform which supports educational activities is presented in this paper. The architecture, which is based on a unifying data model, offers a set of services to control cooperative activities based on either synchronous or asynchronous interaction styles. The software platform built on the proposed architecture can be used for integrating both specialized tools supporting specific educational activities and general purpose tools. The paper introduces the general data model, compares the cost-effective use of communication media with different cooperative styles, and exemplifies the proposed approach with two case studies: an electronic mail-based system for distance tutoring (TEMPO), and a software environment for real-time multimedia conferencing (ImagineDesk). (Contains 23 references.) (AEF)

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An Integrated Environment for Distance Education Supporting Multiple Interaction Styles

S. POZZI
CEFRIEL
Via Emanueli 15, I-20126 Milano, Italy - Tel. +39-2-66100083
Email silvano@mailer.cefriel.it

A. TANCREDI
Via Tribunali 40, I-87100 Cosenza, Italy - Tel. +39-984-21152

F. TISATO
Dipartimento di Scienze dell'Informazione
Via Comelico 39, I-20135 Milano, Italy - Tel. +39-2-55006253
Email tisato@hermes.mc.dsi.unimi.it

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Abstract: The architecture of an open software platform supporting the activities of the educational process is presented. The architecture, which is based on a unifying data model, offers a set of services allowing to control co-operation activities based on either synchronous or asynchronous interaction styles. The software platform built on top of the proposed architecture can be used for integrating both specialized tools supporting specific activities of the educational process and general purpose tools. The paper introduces the general data model, discusses the cost-effective use of communication media in contrast with different co-operation styles, and exemplifies the proposed approach by illustrating two case-studies: an electronic mail-based system for distance tutoring *(TEMPO)*, and a software environment for real-time multimedia conferencing *(ImagineDesk)*.

Keywords: distance learning, synchronous co-operation, asynchronous co-operation, educational process, interaction styles

1. Introduction

The educational process consists basically of communications among the involved actors. First, it relies on the transfer of information from teachers to students (e.g. via "ex cathedra" lessons) and from authors to students (e.g. via textbooks). It also requires bi-directional communication among teachers and students to get feedback from the students, to support their assessment and to provide psychological as well as motivational support. The authoring activity implies communication among authors. Moreover, there are communications among actors involved in different activities of the overall process. Considering a waterfall model of the relationships holding among the phases of a typical educational process (from the definition of goals of the educational process, to the design of a specific course, to the learning phase of the course itself) we notice that people involved in the "higher" phases of the process (e.g., the definition of goals) must communicate with people involved in the "lower" ones (e.g., the design of a specific course). On the other side, feedback must be provided from the lower phases (e.g., learning) to the higher ones (e.g., from curricula definition to authoring).

The achievements of Information Technology (IT) may provide a valuable support for many of the activities and communication styles involved in the educational process. However, the development of IT-based educational systems requires the integration of expertise from two different domains, that is, *Education Science* and *Information Technology*, which are characterised by non-homogeneous theoretical and technological backgrounds. This may lead to systems exhibiting technologically advanced platforms, but poor educational models; in other cases, we observe systems featuring sophisticated educational models without an adequate technological support. Moreover, IT based tools associated to different activities constituting the educational process rely often on different models of the needed information, support different co-operation styles and are based on different media and technologies. As a result, information produced by a given activity can be hardly

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used as input for other activities. Ultimately, it is difficult to effectively manage the educational process as a whole.

This paper is focused on the design of an *integrated* environment supporting different activities and co-operation styles related to a given educational process. The environment defines a uniform model of the data, and uses in a cost-effective way multiple communication media. It is *open-ended* as it allows to smoothly integrate new tools and new media.

In Section 2 we sketch a model of both the educational process and the related data. Then we discuss the relationships holding between co-operation styles and communication media. The use of these concepts is exemplified in Section 3 through the presentation of two real cases. *TEMPO* is a distance tutoring environment which augments a mailing system by embedding it into a context supported by a Data Base of the learning activities. *ImagineDesk* is an environment for real-time conferencing integrating multiple communication media under a user-defined floor control discipline, and providing a platform for the development of multi-user educational applications. *ImagineDesk* provides also a support for planning the execution of co-operative activities. Finally, Section 4 shows how the achievements of *TEMPO* and *ImagineDesk* are going to converge towards a common platform aiming at supporting the overall distance learning process.

2. An Integrated View of the Educational Process

2.1. A Model of the Process

In our view, the educational process can be divided into six main phases: *requirements analysis*, *goals definition* [Mager 62], [Mager 76], [Stone 72], *design*, courseware *implementation*, *curricula management*, and *learning activity* . The goal of our work is not to define *the* ultimate model of the process; related concepts can be found, for instance, in [Carrol 63], [Skinner 68], [Bloom 76]. Our research efforts focuses on the definition of a unifying model [Tancredi 92] which is reasonable and simple enough to be the conceptual framework for the development of an integrated IT platform.

Though the phases are logically ordered, there is - or there should be - a complex and continuous feedback among phases, and inside each phase. It is supported by the *assessment* activity, which allows to measure the degree of achievement of the expected goals [Lindquist 65], [Cronbach 70], [Bloom 72]. It is the basis for evaluating the quality of each phase of the process, and for triggering corrections whenever needed. The assessment activity is performed at different phases and at different abstraction levels ranging from self-assessment to the assessment of the overall process. Note that, as soon as the assessment deals with the activities performed by a groups of actors, the data must be aggregated to generate useful feedback to the higher phases of the process.

2.2. A Uniform Data Model

The activities of the different phases, and the related tools, are often based on different models of the (logically shared) information. This lack of integration may arise either from logical reasons; or it may arise from technological limits. In order to achieve integration at a reasonable cost, all the phases of the process should rely on a uniform model of the data. The Data Model [Barrese 92] [Calabrò 92] is based on objects connected by relations. An "object" is an information structure characterised by the actions an actor can perform on it.

The basic objects model educational *tasks*, which can be hierarchically composed of depending tasks. For instance, a curriculum consists of courses which in turn consist of units. A task is associated to the definition of a *goal*. A goal may be associated to an *assessment procedure*. Tasks at the lowest level *(units)* are composed by *items* (a piece of text, a video, a figure, and so on). The execution of tasks is partially ordered according to two basic relationships: *propaedeutic*, meaning that the contents of a task are a necessary condition for another task, and *taxonomy* [Bloom 56] [Gagné 70] ordering the tasks according to their difficulty. An auxiliary *precedence* relationship may be defined to enforce a specialized path through the tasks.

The network of objects and relations of the data model defines the basic structure of the concrete Data Bases supporting specialized tools, and provides the framework for their integration. Note that this does not mean that all the activities and tools rely on a unique Data Base. What is needed is that all the Data Bases are designed according to the unifying data model, to facilitate the exchange of information among different phases and tools.

2.3. Communication Media and Co-operation Styles

Several different co-operation styles are involved in an educational process, and most of them may be supported by suitable IT tools. The problem is to exploit in a cost-effective way the available communication media in order to support the proper interaction style for each activity. As an example, in the following we provide a

classification of the basic co-operation styles which can be identified in a specific educational activity, that is the learning one, and discuss briefly which communication media are the most suitable for each style.

Communication media fall into two major categories. *Real Time* communication is very effective, but is also very costly in terms of both technological and human resources (because it implies the availability of the actors at given times). *Non Real Time* communication is based on data repositories, supporting asynchronous co-operation [Ellis 91]. Its major advantage is the low cost; it is, however, less impressive and requires some degree of self-motivation.

A second distinction can be done between *symmetric* and *non symmetric* media. The former ones allow all the involved users to play an active role, whereas the latter ones reserve this right to some privileged actors. A major advantage of the symmetric media, which are more expensive, is the psychological and motivational support they provide. Broadcasting media (e.g. video lessons) are examples of real-time, non symmetric communication; conferencing systems are real-time and symmetric; mailing systems and repository systems are non real-time and symmetric; finally, textbooks are examples of non real-time, non-symmetric communication.

Co-operation styles can be classified in a two-dimensional space, whose dimensions represent the degree of prescriptive guidance and the degree of psychological support, respectively. The presented model is derived from models widely used in the area of situational leadership [Hersey 82] [William 67]. During the execution of an educational task, the preferred style for co-operation among students and teachers changes according to a typical path through the styles space.

At the beginning of the task there is a bare transfer of information and of directives from teacher to students. We call this style of co-operation *prescription;* the typical habit of the teacher in this style can be summarised as "that is what you must do (or know)". This style requires a limited degree of interaction among users, therefore it can rely on non-symmetric media: ex-cathedra lessons, distance lessons, textbooks.

As soon as the student encounters some difficulties in its task, he or she needs both prescriptive guidance and psychological support. The proper style in this phase is *explanation*, where the teacher's habit is "you want to do, and I'll show you how to do". The explanation style requires both fine grained guidance and psychological support, therefore real-time and symmetric media are needed. We argue that Real Time interactions require the integration of multiple real-time, symmetric media (text, voice, video, images...) under a common floor control discipline [CSCW 92, CSCW 93]. Most environments for real-time co-operation are built on the top of specific communication media, and do not provide the capability of integrating different media. For instance, it is not straightforward to integrate video conferencing with standard text editing tools in a co-operative environment. In general, the integration in the small should be achieved by means of a platform (see Sec. 3.2) that allows to design and implement co-operative environments by separating the logical aspects (e.g., floor control strategies) from the technological ones (e.g., the management of specific media).

In the next phase the student has achieved a reasonable degree of autonomy from the point of view of the contents of the task, but still needs some psychological support. The proper style is *involvement:* "I believe in your capability, and I am available to support you if you need help". The involvement style relies on a reasonable autonomy of the student, but requires psychological support. Therefore it can be based on non real-time symmetric communication, provided that the actors (in particular, the teacher) have a detailed view of the interaction context (this is the case of the tutoring activity which will be discussed in Section 3.1).

The last co-operation style is *delegation*, that should take place when the student is highly autonomous from both points of views: "the achievement of the goal is up to you". This style implies a high level of motivation and autonomy of the student, who may communicate with the teacher - if needed - via standard symmetric media: mail or telephone.

3. Practical Environments

3.1. TEMPO: an Environment for Distance Tutoring

TEMPO (TEletutoring, Milan, POlytechnic) is an environment supporting distance tutoring. It has been conceived and designed in order to support interactions related to the involvement interaction style, which can be based on non real-time symmetric communication, provided that the actors (in particular, the tutor) have a detailed view of the interaction context. In fact, the major difficulties concerning the communication among tutors and students arise from the lack of context. In particular, the tutor needs a view of the curriculum of the student, of the tasks he or she performed, and of the results of its assessment activities.

TEMPO is constituted of two (conceptually and physically) distinct work environments: the student and the tutor environments. They manage local Data Bases storing *images* of the basic objects and relations. The student DB includes the curriculum of the student, the history its interactions with the tutors, and the learning materials (or suitable references to them). The tutor DB includes the curricula of all the students, the learning materials and the histories of all the interactions. Both student and tutor environments rely on a MS-Windows platform. Student environments have a small local DB containing the student's data only. The tutor

environments rely on a central DB supported by an Oracle DB server. The two environments communicate via e-mail, which is transparently used by *TEMPO* as a communication protocol to enable interactions among actors, and to keep the distributed DBs consistent.

TEMPO augments the e-mail system by embedding each help request into a *context* determined by the actual state of fruition of the learning material, so that the tutor can exactly know to which specific issue the help request is related to. Moreover, the tutor can analyse the curriculum of the student in order to customise the answer. Finally, on both the tutor and student sides a *history* of the interactions is maintained. It is supported by introducing the concept of *communication process*, which consists of a sequence of *communication acts*. The history of each communication process is stored inside the DBs as a time stamped sequence of typed communication acts. Users may navigate through a history, get the most recent acts of a process, get all the acts of a given type, select the acts related to a specific issue, and so on.

TEMPO has been presented here to show how a proper design of the data model provides a sound background for the integration of different activities during the educational process. The student environment supports learning and self-assessment activities. The tutor environment supports tools for tracing the interaction process, for collecting relevant questions, for the assessment of the overall process, and for managing it from an administrative point of view. Though the two environments are quite different, a high degree of integration can be achieved due to the fact that both of them are based on the same data model. The same principle should be applied to specialized environments associated to different phases of the educational process. For instance, information gathered from the tutoring activity (e.g., frequent questions) could easily provide feedback to the curricula management phase.

TEMPO has been developed at CEFRIEL under the sponsorship of the Polytechnic of Milan. A first version is currently used for the distance tutoring of a small (40) group of students in a basic course on Computer Science. An engineered version will be used during 1994 for larger groups.

3.2. ImagineDesk: an Environment for Real-Time Co-operation

ImagineDesk [DiNitto 93, DePaoli 91, DePaoli 93] is a software platform supporting the integration of different communication media in a real-time conferencing context. It can be used to support the explanation style of;co-operation . We define a conference as a system in which users interact in real time through a multimedia *shared workspace* [Ishii 91] constituted of a set of applications. For instance, a conference can be constituted by a spreadsheet, a word processor and a video-audio exchange application, so that interacting users can talk, see each other's face, and work on shared documents. *ImagineDesk* enables to organise and manage a conference by integrating both *co-operation-aware* applications (i.e., specifically developed to support co-operation) and *co-operation-ignorant* applications (i.e., standard off-the-shelf packages) under a common co-operation discipline.

Due to the fact that the collaboration takes place by interacting on a shared workspace, the access to the workspace must be carefully controlled by rules that must be customised to fulfil the requirements of specific activities. *ImagineDesk* considers that within a conference users are characterised by the *roles* they play during the evolution of the co-operative activity. A role defines the rights for performing actions on the shared workspace and for supervising the co-operation. Users playing the same role are collected in a *group*. Users may change their group membership in order to reflect changes of role.

Groups are defined at two different abstraction levels. Groups at the *application layer* correspond to abstract roles that model the access to the shared workspace. Their definition is independent from user identity as well as from system-dependent features, such as communication media. Groups at the *communication layer* model the rights of access to the communication capabilities provided by the underlying hardware/software platform. Group membership changes at the application layer are reflected by corresponding changes at the communication one, according to a mapping relationships. Due to the clean separation between the logical and the physical aspect of the co-operative activity, it is possible to change its logical management without affecting the structure of the application, nor the communication aspects.

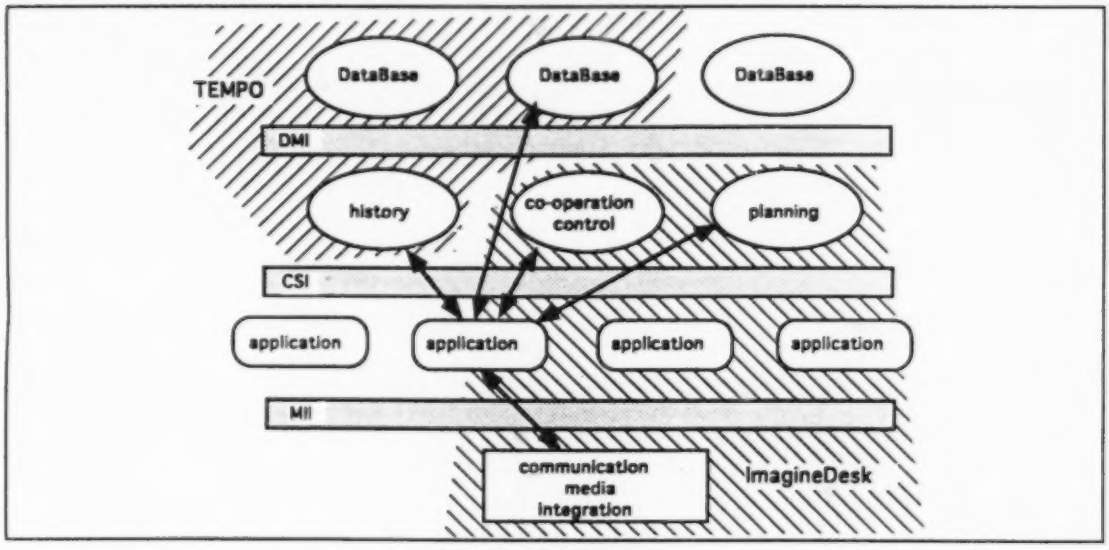
A key phase of a computer-supported co-operative activity (as well as of a real-life one) is the planning of the activity itself. In fact, at a great extent the accuracy of the planning phase (the scheduled start-up time, the set of invited persons, the context of work, and so on) determines the success of the co-operative activity. *ImagineDesk* provides for tools and services which can be exploited in order to effectively organise a co-operative activity. According to the interaction styles taxonomy presented in Section 2.3, these services can be used to properly organise the explanation of an educational topic, taking into account the users involved in the real time interaction, the media used to support the interaction, and the tools used through the interaction. Even during a real-time interaction users can refer to the actual context of fruition of the learning material, by relying upon the data model. For instance, as soon as an help process ends in a "cul de sac", that is, a student (or a group of students) is not able to exceed a specific problem, a real time interaction can be organised. The context of the interaction is the actual state of fruition of the learning material. Moreover, the tutor can decide to use one or

more applications (such as word processor, drawing or simulation tools), in order to help the student solve the task, thus giving guidance and psychological support from a remote site.

The architecture of *ImagineDesk* includes two kinds of processes: *permanent* processes, existing as long as the platform is available, and *transient* processes, existing for a limited amount of time. *ImagineDesk* does not impose specific locations to the processes, unless a process controls specific hardware connected to a given machine. Processes communicate by means of asynchronous message passing. In a typical situation, co-operative applications run on User Workstations, while the processes comprising the platform run on the Conference Server, a workstation through which all control data flows and media flows are routed.

4. Conclusions: Towards an Integrated Environment

The achievements of *TEMPO* and *ImagineDesk* provide a sound basis for the development of an integrated, distributed and open-ended environment supporting the whole educational process. The final goal of the research activity is the definition of a software platform allowing the implementation of specialized components (courseware packages, assessment procedures, co-operative applications, authoring tools, administration services, and so on) on the basis of a uniform framework. The architecture of the environment is shown in the figure. The environment provides a collection of service modules supporting general purpose functionalities related to the communication among users: planning, history, and co-operation control. These modules are viewed by application programs through a suitable application programming interface (*Co-operation Services Interface*, CSI) hiding system dependent issues and providing a uniform view of the services.



The Integrated Environment.

The basis for the integration of specialised applications is provided by a common interface to Data Base services (*Data Model Interface*, DMI) based the general data model, no matter how and where it is implemented in terms of specific Data Bases. Both service modules and specialized tools rely on DMI.

Finally, the integration of different communication media is provided by a *Media Integration Interface* (MII) that provides a uniform visibility of the media.

As shown in the figure, all these issues are tackled by either *TEMPO* or *ImagineDesk*. The data model of *TEMPO* provides a general framework for the integration of tools devoted to specific activities and for the feedback among the phases of the education process. *TEMPO* supports also the concept of history of communication processes, that could involve different activities and tools. On the other hand, *ImagineDesk* provides a valuable support for planning and managing the activities, for integrating different applications under a common discipline, and for integrating different communication media in the context of an application.

Ultimately, the authors believe that the bricks are here, and that the integrated environment is partially built. Further efforts will be devoted to its experimental use, to its evolution towards an engineered platform, and to the development of specialized tools. The open-ended approach of the project allows to devise a stepwise strategy for the implementation of the overall environment. The experimental use of *TEMPO* will allow to test the consistency of the data model, to define the logical structure of a significant collection of courses, to collect and

organise data related to a large group of students, and to experiment the practical use of the tutoring environment. This activity has been already started and will have a first milestone at mid 1994. Meanwhile the definition and experimentation of tools supporting assessment will be carried on, in order to support feedback in the learning activity. At this point, the skeleton of a technological, organisational and methodological framework will be available.

In parallel, the *ImagineDesk* platform will be enhanced by integrating new communication media (in particular, ISDN for supporting multimedia interaction over public networks), by extending the mechanisms for the definition of flexible co-operation strategies, and by building user-friendly interfaces for the co-operation control. Moreover, some experimental courseware packages for real-time, multi-user teaching/learning activities will be developed and tested.

Further steps will be oriented to the definition and development of specialized tools for curricula definition, authoring, and management of the overall process. Courseware packages will be gradually integrated as soon as they will become available; the value of the environment, however, derives mainly from its ability to provide an integrated framework from the organisational and methodological point of view, and is not heavily bound to the availability of complete sets of courseware packages.

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